AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9036

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 622

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
BLACKHAWK GEOSERVICES
301 COMMERCIAL ROAD, SUITE B
GOLDEN, CO 80401

TECHNOLOGY TYPE/PLATFORM:
SIMULTANEOUS MAGNETOMETRY AND
PULSED EM/MAN-PORTABLE

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

JULY 2005

Prepared for:
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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The Standardized UXO Technology Demonstration Site Scoring Committee

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14. ABSTRACT
This scoring record documents the efforts of Blackhawk Geoservices. to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. Scoring Records have been coordinated by Larry Overbay and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include, the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center.

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (AEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e. that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-mm, 40-mm, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm HEAT Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb
	M75 Submunition

JPG = Jefferson Proving Ground.
HEAT = high-explosive antitank

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

Blackhawk GeoServices
301 Commercial Road, Suite B
Golden, CO 80401

2.1.2 System Description (provided by demonstrator)

Simultaneous Magnetometry and Pulsed electromagnetic (EM) recorded and controlled in one unit. The approach Blackhawk will demonstrate is a small hand towed trailer one-man EM/MAG system (fig. 1). The proposed AGS1-MK-II system will record four Cesium magnetometer sensors (Geometrics G822/A) as well as an EM61 MK-II system. The cesium vapor sensors will be sampled during the 'off' time of the EM pulse. When set for operation in 60Hz power areas, the EM61 MK-II continuously emits EM pulses at a repetition rate of 75 Hz. Given a decay time of approximately 8 msec, this leaves a further 5 msec during which the larmor signals from the magnetometer systems can be counted and measured.

Figure 1. Demonstrator's system, simultaneous magnetometry and pulsed EM/man-portable.

The AGS1-MK-II system uses proprietary counters implemented in FPGA (Field Programmable Gate Array) integrated circuits to measure the frequency of the larmor signal with a resolution of approximately 0.015 nT in a time of 5 msec. The actual measurement time used can be controlled by the operator from between 1.3 msec (resolution approximately 0.1nT) to 30 msec (0.001nT).

The sync output pulse of the EM61 MK-II is used to synchronize the counters of the AGS1-MK-II so that they begin a measurement of the larmor frequency at a programmable delay time after the falling edge of the 4 msec wide sync pulse.

The operation of the AGS1-MK-II and the recording of data is controlled over a single standard 115Kbaud RS232 link by a notebook PC running custom data acquisition software (AGS dat) under Windows 2000. The AGS1-MK-II uses dual 32 bit embedded processors, each controlling 2 larmor counters as well as sharing the handling of the data from the other sensors. The single logged file is then processed to give both a magnetic data grid and an EM data grid.

Main System Components:

- 4 cesium vapor sensors
- 1 EM MK-II sensors
- SeaTerra AGS MK-II system controller
- DGPS (Trimble 5700 with base station or Trimble AG-Global Positioning System (GPS) with satellite reference signal)
- optional 3-axis digital compass
- optional 3D component fluxgate magnetometer for compensation
- notebook computer
- proprietary data recording and navigational software AGSDat
- navigation instruments and displays
- proprietary data processing software AGSProc
- Platforms: hand carried one and two man system; hand towed one man system; vehicle towed trailer system

2.1.3 Data Processing Description (provided by demonstrator)

Blackhawk will collect data in this area using GPS positioning methods. The GPS antennae will be located on the sensor cart mounted directly over the center of the sensor arrays. The sensor array will consist of four G858 sensors spaced 0.33 meters apart and a 1.0-meter by 0.5-meter EM61 MK-II coil, resulting in a 1-meter sample width. Position data will be recorded on the AGS-MK-II data logger along with the sensor data. The AGS1-MK-II system is also used to record the EM61 MK-II data. The magnetic data is recorded in distance mode at 5 cm intervals using a cotton thread odometer or a wheel trigger and/or DGPS. The EM61 MK-II data is recorded in distance mode using the wheel odometer to give 20 cm samples.

The raw data from the AGS-MK-II is output in a binary format. The binary format is converted to American Standard for Information Interchange (ASCII) with the AGSProc processing software. Numerous import and export options of the AGSProc software making the system open for allow for data exchange (GIS, CAD, XYZ, and Geosoft formats).

Prior to data collection, Blackhawk will survey a grid system over the site on 200 ft by 200 ft centers. Data will be collected within the 200 ft grids. Measuring tapes will be stretched across the boundaries of the grid and at several locations within the gird. The number of markings will depend on the openness of the terrain. Data will be collected along nominal 2.5 to 3.0 foot line spacings. Traffic cone markers will be placed along the tapes and moved as the equipment operator passes the tape. This will ensure that the sensor array maintains nominal 2.5 to 3-foot spacing between survey lines. The actual position of the geophysical sensors will be determined from the GPS.

In those areas of the open field test site where there are obstructions, the established grids will be 100 feet by 100 feet to ensure coverage.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

Overview of Quality Control (QC).

The positioning information, survey setup parameters and sensor data are recorded on a mobile laptop computer/field data logger. The data recording allows real time control and display of all survey information and the survey data. A programmable acoustic tone is used to indicate to the operator monitor the signal level from one or more of the sensors. This is basically real time data quality control, which is very useful because the operator is not able to watch the display all the time during fieldwork. The navigational display shows real time sensor tracks overlaid on the survey map. WGS 84 coordinates are transformed in real time into local or Universal Transverse Mercator (UTM) coordinates. Sensor signal data, speed, compass information as well as technical parameters like battery voltage etc. are visible in real time for the operator. The first initial data processing is optimized allowing the data to be processed onsite. The proprietary data processing software AGSpProc is used to view the recorded raw data as profile lines and as a gridded image. Viewing this data takes a few minutes and allows an immediate control of the data quality as well as the coverage of the area in the field.

Prior to data collection, all electronic equipment is turned on and warmed up for a minimum of 15 minutes. After warm up, data are recorded for the EM and magnetic sensors for three minutes. This information is used to verify the proper performance of the sensors prior to collection of survey data. In addition, data are recorded over a ferrous metal standard located in the same position relative to the geophysical sensors on a daily basis. This ensures that sensor response is consistent throughout the survey. Positional accuracy of the system is also verified on a daily basis by data collection over a point whose absolute location is known. Data are collected in opposite travel directions in two traverses across the point. This data is recorded and used to verify the GPS is operating correctly. If during the real time monitoring of the survey data the operator suspects that all or a portion of the system is not operating correctly, the QC tests are repeated.

Overview of Quality Assurance (QA).

Blackhawk has conducted geophysical surveys for government and private clients during which stringent QA/QC procedures have been required. Blackhawk's corporate QA/QC program is developed to provide guidance for all divisions of the firm. QA/QC procedures are applied to each project and peer review of work/reports is the standard protocol.

Blackhawk management identifies project key project personnel and project team members with designated responsibilities and requirements. The project manager (PM) meets the qualification requirements of the project, including education, experience, and registrations. The PM or if applicable, the QA/QC officer, ensures equipment validation including equipment testing for representativeness in addition to correctness for expected result along with equipment standardization for functionality and optimization to meet acceptance criteria.

There is also verification of format for deliverables (e.g., data and reports) and their schedule as well as data recording and documentation; data transmission and verification that all recorded data are present; and data monitoring which includes monitoring the standardization parameters required to meet the acceptance criteria, including monitoring for accuracy and precision. Data evaluation includes data interpretation and reporting.

Final reporting of all these actions includes peer review/senior review approval.

As a result of this successful QA/QC program, Blackhawk and Blackhawk-led teams have well-defined responsibilities that include stop-work authority and organizational freedom to identify problems and to evaluate, initiate, recommend or provide solutions; and to approve corrective actions thus ensuring that all work complies with stipulated contractual requirements.

2.1.6 <u>Additional Records</u>

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area of APG. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods, and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consists of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15- and 30-percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration.
Blind Grid	Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter or nothing.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (24 August 2004)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration Lanes	2.92
Blind Grid	1.75

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2004	Average Temperature, ^{o}F	Total Daily Precipitation, in.
August 24	79.06	0.00

3.3.2 Field Conditions

Blackhawk surveyed the Blind Grid on 24 August 2004. The Calibration Lanes and Blind Grid had several muddy areas due to rain prior to testing.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: Calibration, Mogul, Open Field, and Wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. A three-person crew took 13 hours and 15 minutes to perform the initial setup and mobilization. There was no daily equipment preparation and end of the day equipment break down lasted 35 minutes.

3.4.2 Calibration

Blackhawk spent a total of 2 hour and 55 minutes in the calibration lanes, of which 1-hour and 15 minutes was spent collecting data. An additional 25 minutes was spent calibrating in the Blind Grid.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, Demonstration Site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to Demonstration Site issues. Demonstration Site issues, while noted in the Daily Log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total Site Survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for no site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. Blackhawk spent no additional time for breaks and lunches.

3.4.3.2 Equipment failure or repair. No time was needed to resolve equipment failures that occurred while surveying the Blind Grid.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

Blackhawk spent a total time of 1-hour and 45 minutes in the Blind Grid area, 1-hour and 10 minutes of which was spent collecting data.

3.4.5 Demobilization

The Blackhawk survey crew went on to conducted a full demonstration of the site. Therefore, demobilization did not occur until 2 September 2004. On that day, it took the crew 1-hour and 35 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Blackhawk submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD SURVEYING METHOD

Blackhawk surveyed the Blind Grid starting in the northeast corner of the grid and in a east/west direction. Blackhawk surveyed the Blind Grid in a linear fashion.

3.7 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2, 4, and 6 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive for the EM sensor(s), MAG sensor(s) and combined EM/MAG picks respectively. Figure 3, 5, and 7 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in figures 4 and 5 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

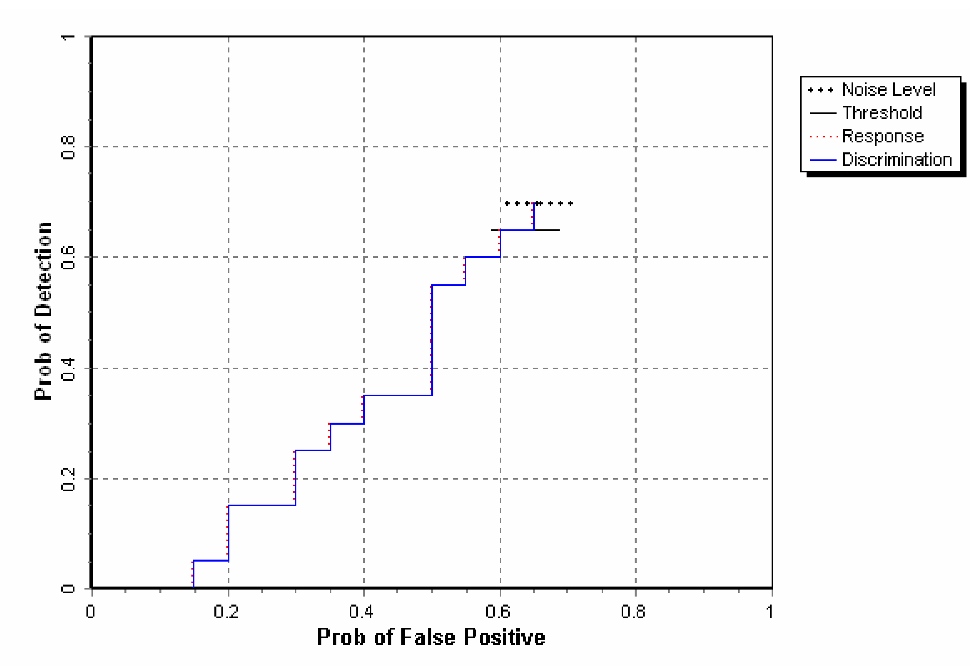

Figure 2. Pulsed EM blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

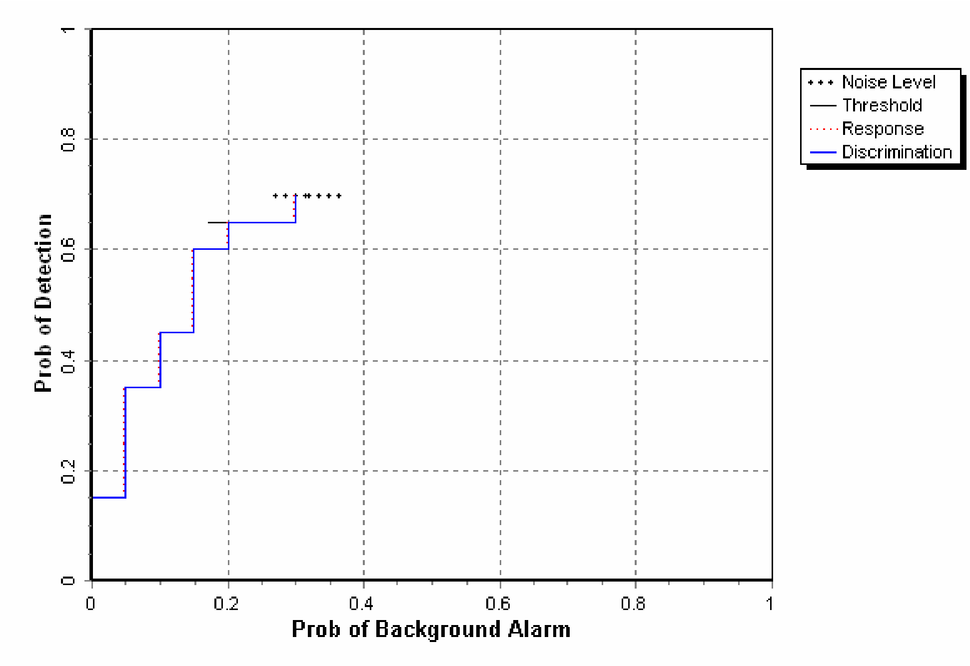

Figure 3. Pulsed EM blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

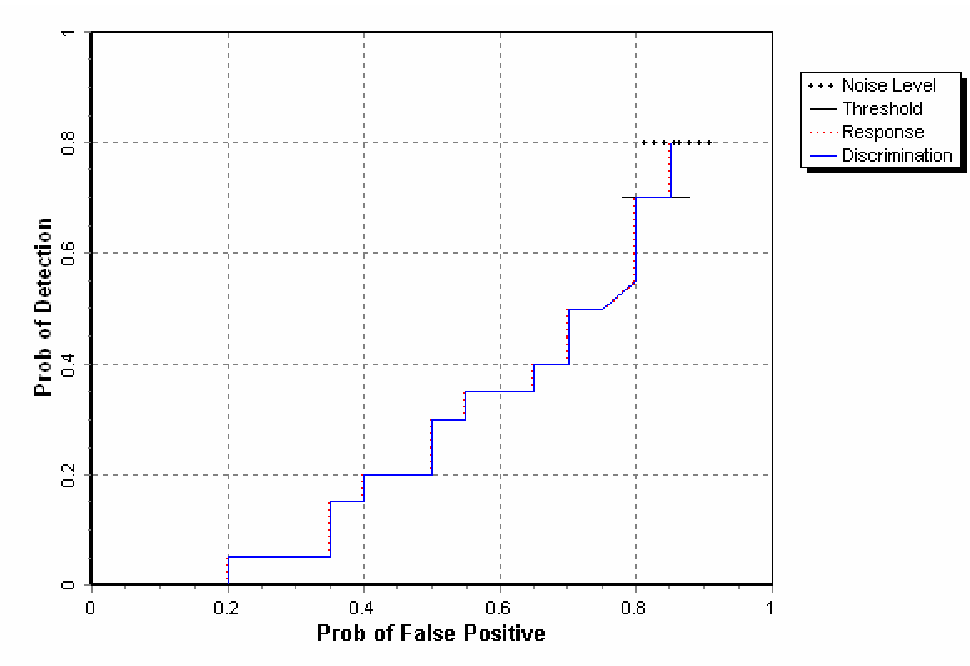

Figure 4. Simultaneous Magnetometry blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

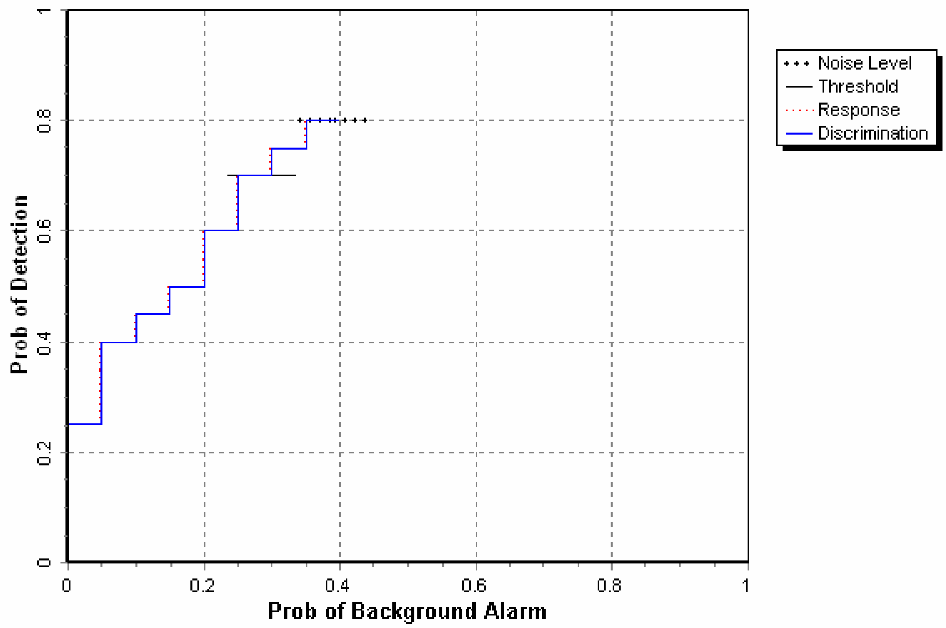

Figure 5. Simultaneous Magnetometry blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

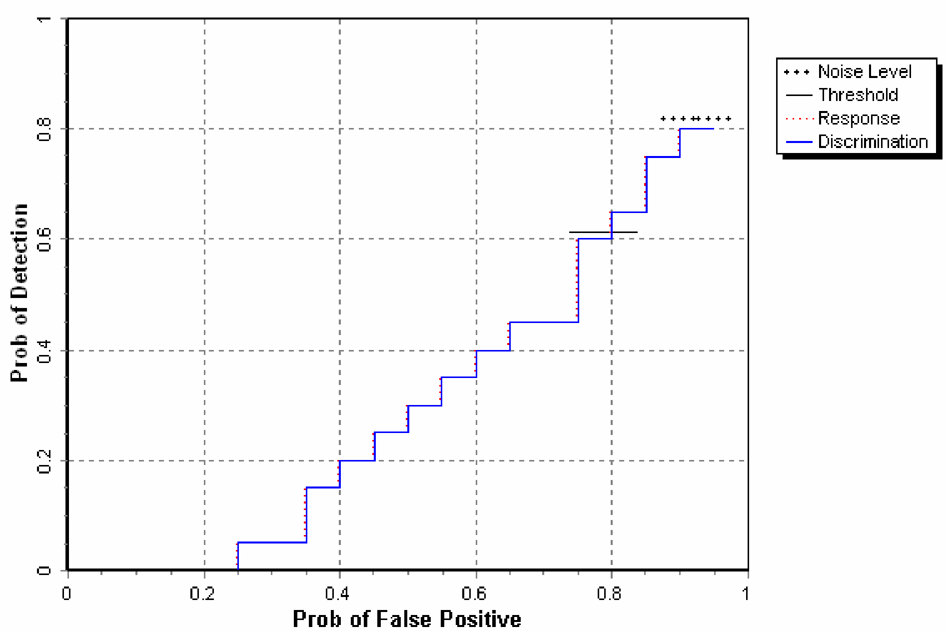

Figure 6. Combined sensor blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

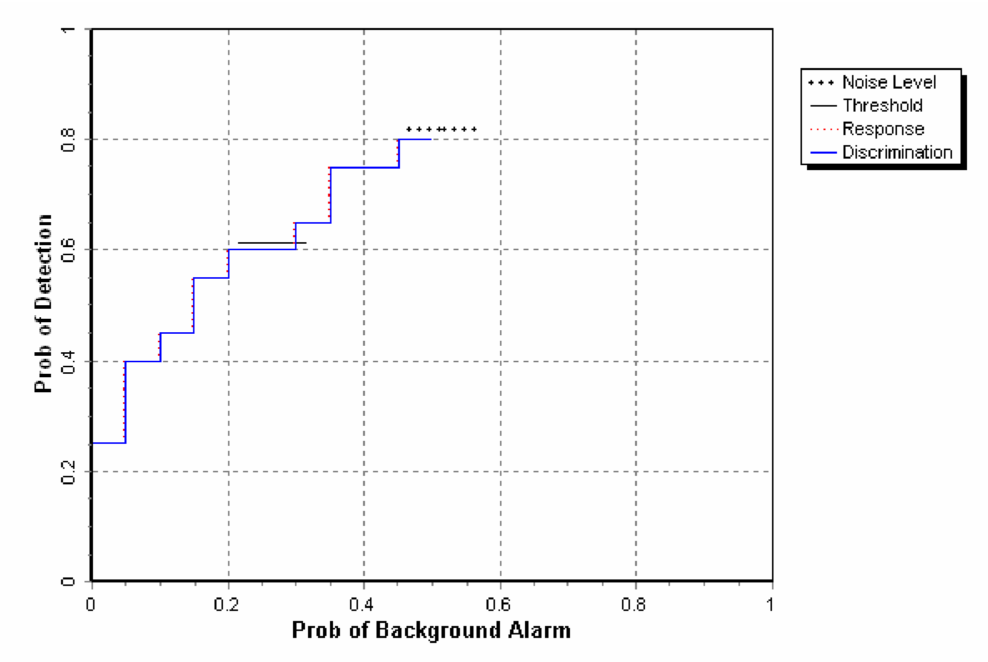

Figure 7. Combined sensor blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 8, 10, and 12 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored for the EM sensor(s), MAG sensor(s) and Combined EM/MAG picks respectively. Figure 9, 11, and 13 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the ROC curves presented in figures 10 and 11 of this section are based on the subset of the ground truth that is solely made up of ferrous anomalies.

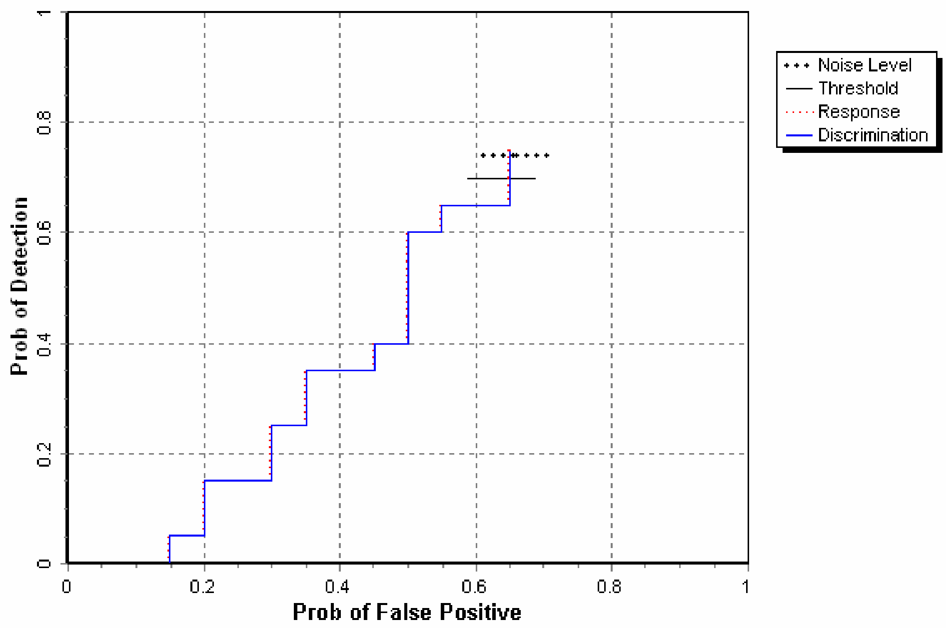

Figure 8. Pulsed EM blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

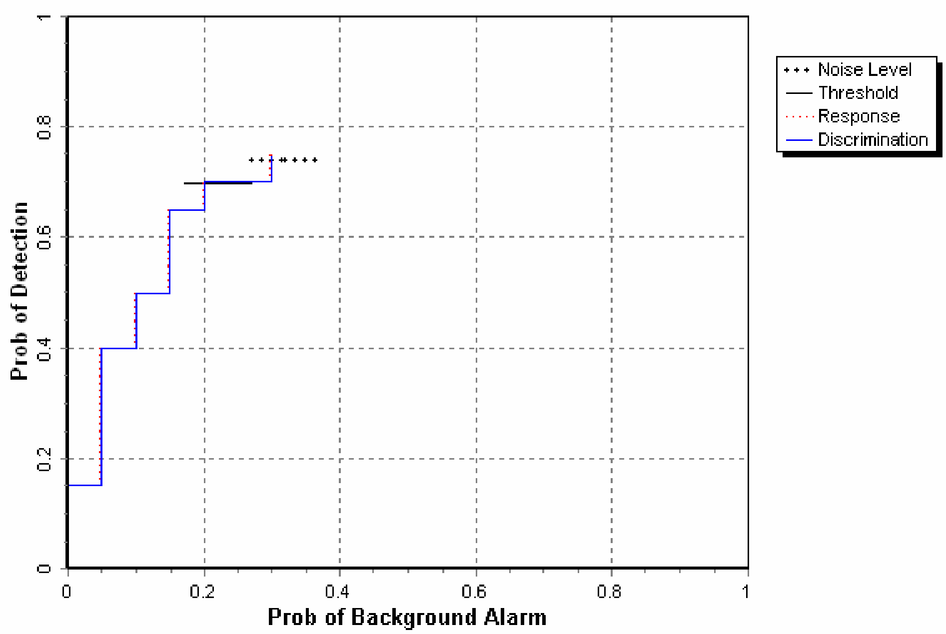

Figure 9. Pulsed EM blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

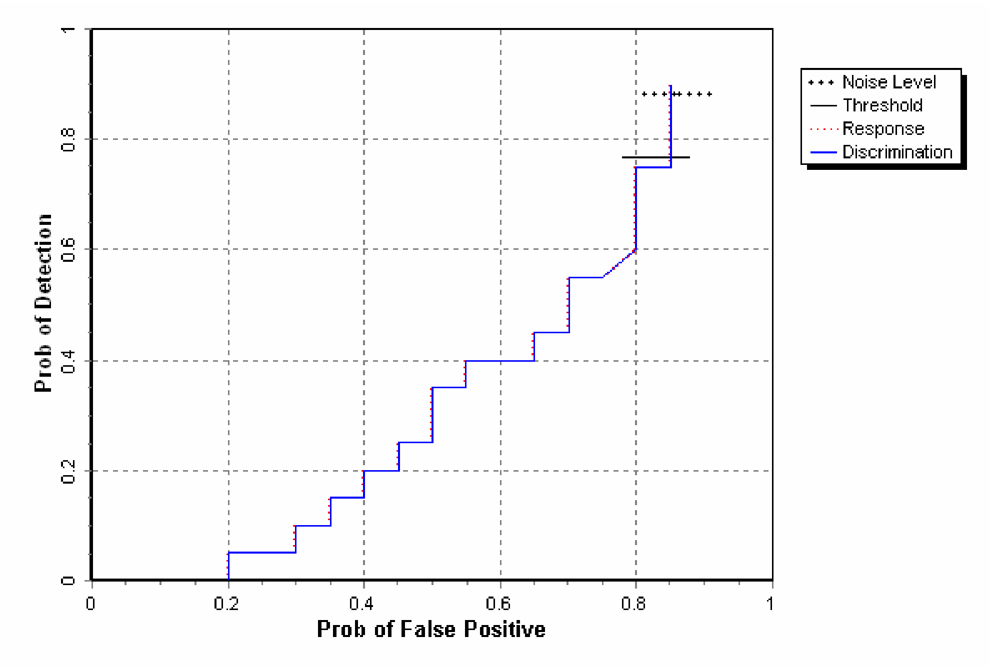

Figure 10. Simultaneous Magnetometry blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

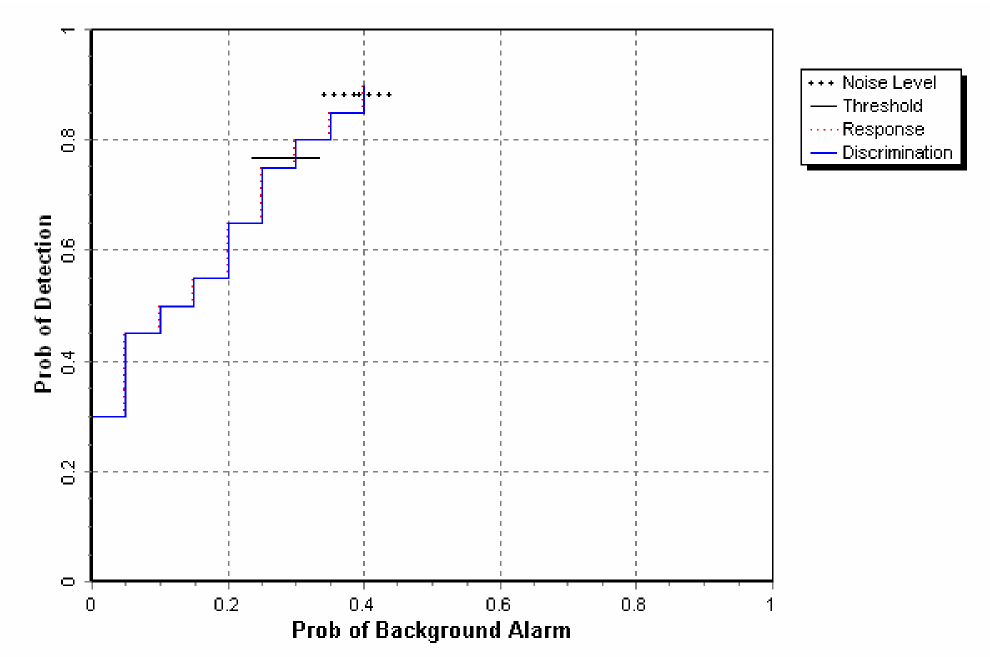

Figure 11. Simultaneous Magnetometry blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

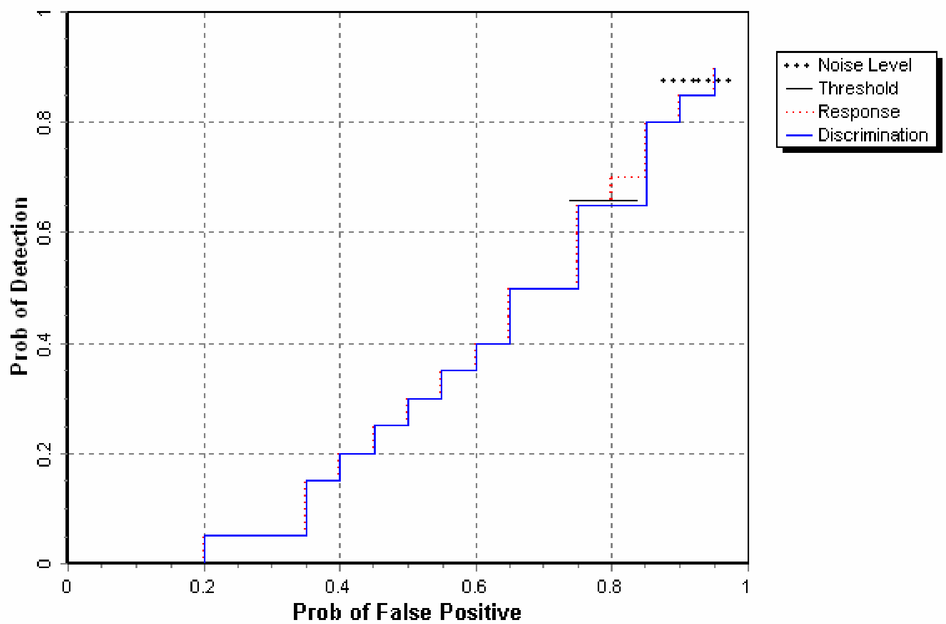

Figure 12. Combined sensor blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

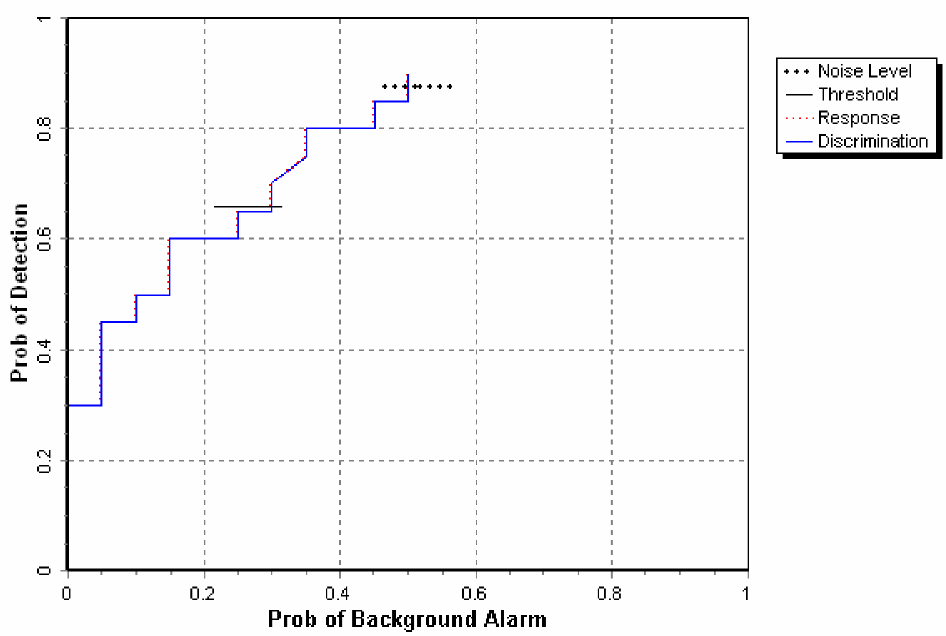

Figure 13. Combined sensor blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the Blind Grid test broken out by sensor type, size, depth and nonstandard ordnance are presented in Tables 5a, b, and c (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the summary presented in Table 5b is split exhibiting results based on the subset of the ground truth that is solely the ferrous anomalies and the full ground truth for comparison purposes.

All other tables presented in this section are based on scoring against the ferrous only ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

TABLE 5a. SUMMARY OF BLIND GRID RESULTS FOR THE PULSE EM

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.70	0.70	0.70	0.65	0.70	0.80	0.75	0.80	0.45
P_d Low 90% Conf	0.63	0.61	0.56	0.56	0.58	0.55	0.61	0.67	0.24
P_d Upper 90% Conf	0.77	0.79	0.80	0.76	0.82	0.95	0.82	0.89	0.63
P_{fp}	0.65	-	-	-	-	-	0.70	0.60	0.60
P_{fp} Low 90% Conf	0.59	-	-	-	-	-	0.60	0.51	0.25
P_{fp} Upper 90% Conf	0.72	-	-	-	-	-	0.79	0.72	0.89
P_{ba}	0.30	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.65	0.65	0.65	0.60	0.65	0.80	0.70	0.70	0.35
P_d Low 90% Conf	0.58	0.57	0.50	0.51	0.51	0.55	0.59	0.59	0.19
P_d Upper 90% Conf	0.72	0.75	0.74	0.72	0.76	0.95	0.80	0.83	0.56
P_{fp}	0.65	-	-	-	-	-	0.70	0.60	0.60
P_{fp} Low 90% Conf	0.57	-	-	-	-	-	0.58	0.48	0.25
P_{fp} Upper 90% Conf	0.70	-	-	-	-	-	0.77	0.70	0.89
P_{ba}	0.20	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.39
Recommended Discrimination Stage Threshold: -0.06

TABLE 5b. SUMMARY OF BLIND GRID RESULTS FOR THE SIMULTANEOUS MAGNETOMETRY

Ferrous only Ground Truth									
				By Size			By Depth, m		
Metric	Overall	Standard	Nonstandard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.80	0.85	0.70	0.70	0.85	0.90	0.80	0.85	0.70
P_d Low 90% Conf	0.73	0.78	0.53	0.55	0.76	0.66	0.67	0.73	0.48
P_d Upper 90% Conf	0.86	0.93	0.80	0.80	0.94	0.99	0.89	0.94	0.86
P_{fp}	0.85	-	-	-	-	-	0.85	0.90	1.00
P_{fp} Low 90% Conf	0.80	-	-	-	-	-	0.74	0.79	0.63
P_{fp} Upper 90% Conf	0.91	-	-	-	-	-	0.90	0.94	1.00
P_{ba}	0.40	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.70	0.70	0.70	0.55	0.75	0.90	0.70	0.80	0.55
P_d Low 90% Conf	0.62	0.61	0.53	0.42	0.65	0.66	0.55	0.65	0.33
P_d Upper 90% Conf	0.77	0.80	0.80	0.68	0.87	0.99	0.80	0.88	0.74
P_{fp}	0.85	-	-	-	-	-	0.80	0.85	1.00
P_{fp} Low 90% Conf	0.77	-	-	-	-	-	0.69	0.76	0.63
P_{fp} Upper 90% Conf	0.88	-	-	-	-	-	0.86	0.92	1.00
P_{ba}	0.30	-	-	-	-	-	-	-	-

(Full Ground truth)									
				By Size			By Depth, m		
Metric	Overall	Standard	Nonstandard	Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.70	0.80	0.60	0.55	0.85	0.90	0.65	0.85	0.65
P_d Low 90% Conf	0.65	0.71	0.47	0.46	0.76	0.66	0.54	0.74	0.44
P_d Upper 90% Conf	0.79	0.87	0.71	0.68	0.94	0.99	0.75	0.94	0.81
P_{fp}	0.85	-	-	-	-	-	0.85	0.90	1.00
P_{fp} Low 90% Conf	0.80	-	-	-	-	-	0.74	0.79	0.63
P_{fp} Upper 90% Conf	0.91	-	-	-	-	-	0.90	0.94	1.00
P_{ba}	0.40	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.65	0.65	0.60	0.50	0.75	0.90	0.60	0.80	0.50
P_d Low 90% Conf	0.56	0.57	0.47	0.37	0.65	0.66	0.46	0.67	0.30
P_d Upper 90% Conf	0.71	0.75	0.71	0.59	0.87	0.99	0.68	0.89	0.70
P_{fp}	0.85	-	-	-	-	-	0.80	0.85	1.00
P_{fp} Low 90% Conf	0.77	-	-	-	-	-	0.69	0.76	0.63
P_{fp} Upper 90% Conf	0.88	-	-	-	-	-	0.86	0.92	1.00
P_{ba}	0.30	-	-	-	-	-	-	-	-

Response Stage Noise Level: 1.00
Recommended Discrimination Stage Threshold: 0.00

TABLE 5c. SUMMARY OF BLIND GRID RESULTS FOR THE COMBINED SENSOR RESULTS

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.80	0.90	0.70	0.75	0.90	0.90	0.80	0.95	0.70
P_d Low 90% Conf	0.75	0.83	0.56	0.63	0.80	0.66	0.67	0.83	0.51
P_d Upper 90% Conf	0.87	0.95	0.80	0.83	0.96	0.99	0.86	0.98	0.87
P_{fp}	0.95	-	-	-	-	-	0.90	0.95	1.00
P_{fp} Low 90% Conf	0.88	-	-	-	-	-	0.84	0.85	0.63
P_{fp} Upper 90% Conf	0.96	-	-	-	-	-	0.96	0.97	1.00
P_{ba}	0.50	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.60	0.65	0.55	0.50	0.70	0.70	0.70	0.65	0.35
P_d Low 90% Conf	0.54	0.57	0.40	0.41	0.45	0.45	0.56	0.52	0.19
P_d Upper 90% Conf	0.69	0.75	0.66	0.63	0.82	0.88	0.77	0.77	0.56
P_{fp}	0.80	-	-	-	-	-	0.75	0.80	1.00
P_{fp} Low 90% Conf	0.72	-	-	-	-	-	0.67	0.68	0.63
P_{fp} Upper 90% Conf	0.84	-	-	-	-	-	0.85	0.87	1.00
P_{ba}	0.25	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.40
Recommended Discrimination Stage Threshold: -0.06

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION (All results based on combined EM/MAG data set)

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	0.75	0.15	0.49
With No Loss of P_d	1.00	0.00	0.00

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	0.0
Medium	0.0
Large	14.3
Overall	2.0

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the Blind Grid, only depth errors are calculated, since (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)

	Mean	Standard Deviation
Depth	N/A	N/A

Note: Demonstrator did not attempt to declare depth of detection.

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor", the second person was designated "data analyst", and the third and following personnel were considered "field support". Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the Calibration Lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	13.25	$1,258.75
Data Analyst	1	57.00	13.25	755.25
Field Support	1	28.50	13.25	377.63
SubTotal				**$2,391.63**
Calibration				
Supervisor	1	$95.00	3.33	$308.75
Data Analyst	1	57.00	3.33	185.25
Field Support	1	28.50	3.33	94.91
SubTotal				**$588.91**
Site Survey				
Supervisor	1	$95.00	1.75	$166.25
Data Analyst	1	57.00	1.75	99.75
Field Support	1	28.50	1.75	49.88
SubTotal				**$315.88**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	1.58	$150.10
Data Analyst	1	57.00	1.58	90.06
Field Support	1	28.50	1.58	45.03
Subtotal				**$285.19**
Total				**$3,581.61**

Notes: Calibration time includes time spent in the Calibration Lanes as well as calibration before each data run.
Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO DATE

No comparisons to date.

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

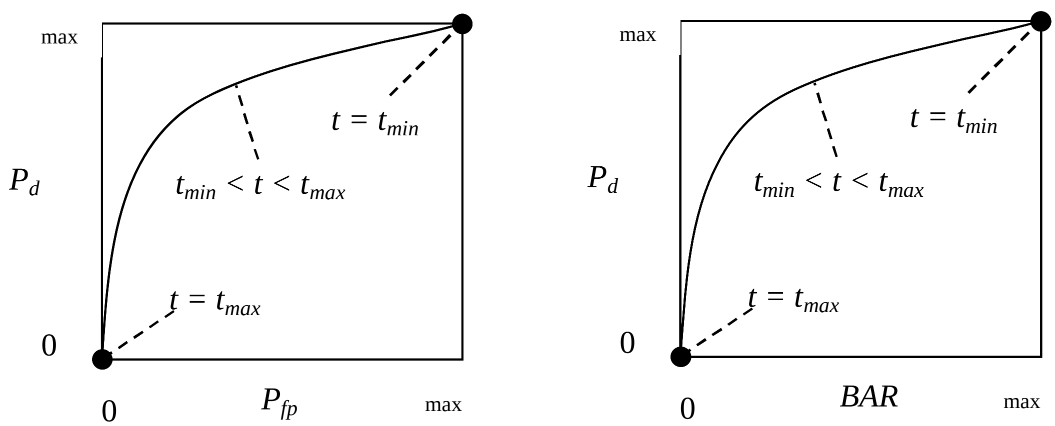

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

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[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X’s system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind Grid	Open Field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B. DAILY WEATHER LOGS

TABLE B-1. WEATHER LOG

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
08/23/2004 07:00:00	61.1	63.6	59	100	0
08/23/2004 08:00:00	67.7	71.7	63.6	95.2	0
08/23/2004 09:00:00	72.9	74.2	71.5	81.8	0
08/23/2004 10:00:00	75	76.6	73.7	75.84	0
08/23/2004 11:00:00	77.8	79.2	75.8	68.92	0
08/23/2004 12:00:00	79.5	81.3	78.4	60.84	0
08/23/2004 13:00:00	81.6	82.5	80.3	56.37	0
08/23/2004 14:00:00	80.7	82	79	64	0
08/23/2004 15:00:00	81.5	83	79.3	61.76	0
08/23/2004 16:00:00	81.4	82.2	80.8	60.72	0
08/23/2004 17:00:00	81.3	81.8	80.7	59.69	0
08/24/2004 07:00:00	65.4	69.1	62.2	99.7	0
08/24/2004 08:00:00	72.5	76	68.7	86.7	0
08/24/2004 09:00:00	76.7	78	75.1	77.2	0
08/24/2004 10:00:00	78.3	79.6	77.3	76.35	0
08/24/2004 11:00:00	79.8	81.1	78.7	74.06	0
08/24/2004 12:00:00	81.6	82.5	80.7	70.47	0
08/24/2004 13:00:00	82.7	83.8	81.9	68.42	0
08/24/2004 14:00:00	83.2	84.3	82.1	68.12	0
08/24/2004 15:00:00	84.3	85.4	83.2	65.28	0
08/24/2004 16:00:00	84	84.9	83.4	66.58	0
08/24/2004 17:00:00	81.2	84.3	79.4	74.35	0

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
08/25/2004 07:00:00	70.7	71.2	70.2	93.6	0
08/25/2004 08:00:00	70.9	71.4	70.5	94.2	0
08/25/2004 09:00:00	71.7	73.3	70.5	94.8	0
08/25/2004 10:00:00	73.8	74.8	73	88.5	0
08/25/2004 11:00:00	74.2	74.9	73.5	87.4	0
08/25/2004 12:00:00	75.9	78.1	74.3	84.4	0
08/25/2004 13:00:00	77.3	78.2	76.3	81	0
08/25/2004 14:00:00	78.8	80.7	77.7	77.28	0
08/25/2004 15:00:00	80.1	80.9	78.7	74.54	0
08/25/2004 16:00:00	79.7	80.3	79	73.61	0
08/25/2004 17:00:00	78.8	79.6	77.9	74.39	0
08/26/2004 07:00:00	69.6	70.5	68.7	96.9	0
08/26/2004 08:00:00	71	71.9	70.1	94.2	0
08/26/2004 09:00:00	72.9	74.4	71.5	90.6	0
08/26/2004 10:00:00	76.1	78.8	74	82.9	0
08/26/2004 11:00:00	78.7	80	77.5	75.21	0
08/26/2004 12:00:00	80.4	81.4	78.9	71.36	0
08/26/2004 13:00:00	80.7	82.3	78.8	69.9	0
08/26/2004 14:00:00	81.4	83.1	80.2	67.52	0
08/26/2004 15:00:00	82.3	83.2	81.1	67.03	0
08/26/2004 16:00:00	81.9	83.1	80.7	69.93	0
08/26/2004 17:00:00	81.8	82.7	80.3	71.37	0

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
08/27/2004 07:00:00	73.3	73.9	72.6	99.6	0
08/27/2004 08:00:00	76.3	78.1	73.7	92.4	0
08/27/2004 09:00:00	77.8	79.1	76.8	82.4	0
08/27/2004 10:00:00	80.2	81.3	78.7	76.43	0
08/27/2004 11:00:00	81	81.9	79.1	74.26	0
08/27/2004 12:00:00	82.2	83.8	81.2	70.13	0
08/27/2004 13:00:00	83.6	84.6	83	65.96	0
08/27/2004 14:00:00	84.2	85	83.4	63.16	0
08/27/2004 15:00:00	84.6	85.4	84	60.43	0
08/27/2004 16:00:00	85	85.5	84.4	56.99	0
08/27/2004 17:00:00	84.1	85	83.2	60.72	0
08/28/2004 07:00:00	75.3	76.2	74	94.1	0
08/28/2004 08:00:00	77.2	78.4	75.8	89.4	0
08/28/2004 09:00:00	78.9	80.4	77.5	84.3	0
08/28/2004 10:00:00	81.1	82.9	79.8	78.72	0
08/28/2004 11:00:00	83.5	85.2	82.1	75.25	0
08/28/2004 12:00:00	85.8	87.2	84.1	72.11	0
08/28/2004 13:00:00	86.5	87	86.1	71.21	0
08/28/2004 14:00:00	87.2	88	86.3	66.5	0
08/28/2004 15:00:00	87.9	88.6	87.1	63.68	0
08/28/2004 16:00:00	87.5	88	86.8	64.72	0
08/28/2004 17:00:00	86.5	87.4	85.6	66.62	0

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
08/29/2004 07:00:00	71.7	75.3	69.6	100	0
08/29/2004 08:00:00	77.1	79.1	75	93	0
08/29/2004 09:00:00	80	81.6	78.7	85.3	0
08/29/2004 10:00:00	81.5	83.1	80.1	80.7	0
08/29/2004 11:00:00	82.9	83.7	81.9	73.93	0
08/29/2004 12:00:00	85.3	86.7	82.7	63.62	0
08/29/2004 13:00:00	86.6	87.4	86.1	59.23	0
08/29/2004 14:00:00	86.8	87.7	85.7	60.73	0
08/29/2004 15:00:00	87.2	88	86.1	54.74	0
08/29/2004 16:00:00	87.3	88.3	86.4	51.2	0
08/29/2004 17:00:00	85.7	87.6	83.7	56.01	0
08/30/2004 07:00:00	74.5	75.5	73.5	98.6	0
08/30/2004 08:00:00	76.2	77	75.1	95.9	0
08/30/2004 09:00:00	77.1	77.5	76.7	92.5	0
08/30/2004 10:00:00	78.9	79.9	77.3	90.7	0
08/30/2004 11:00:00	80.1	80.6	79.4	87.6	0
08/30/2004 12:00:00	79.1	80.4	78.2	89.2	0
08/30/2004 13:00:00	79	80.1	78.1	91.9	0
08/30/2004 14:00:00	80.8	83.1	79.2	86.1	0
08/30/2004 15:00:00	82.2	84.1	81.1	80.5	0
08/30/2004 16:00:00	81.8	82.7	81.2	82.5	0
08/30/2004 17:00:00	81.2	81.7	80.7	84.4	0

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
08/31/2004 07:00:00	74.7	75.1	74.3	84.4	0
08/31/2004 08:00:00	76	77	74.8	80.1	0
08/31/2004 09:00:00	78	78.9	76.6	75.17	0
08/31/2004 10:00:00	79.3	80.7	78.1	71.22	0
08/31/2004 11:00:00	79.7	80.8	78.2	68.23	0
08/31/2004 12:00:00	81	82.1	79.7	66.26	0
08/31/2004 13:00:00	80.8	81.9	79.9	64.85	0
08/31/2004 14:00:00	81	82	80.1	63.31	0
08/31/2004 15:00:00	81.7	83	80.4	61.85	0
08/31/2004 16:00:00	81.4	82.3	80.2	61.92	0
08/31/2004 17:00:00	80.9	82	80.3	61.56	0
09/01/2004 07:00:00	67	69.7	63.9	91.7	0
09/01/2004 08:00:00	72.3	75.3	68.7	77.88	0
09/01/2004 09:00:00	75.3	77.1	73.5	65.94	0
09/01/2004 10:00:00	77.6	79.1	76.2	58.52	0
09/01/2004 11:00:00	79.2	80.5	78.1	51.61	0
09/01/2004 12:00:00	80.6	81.5	79.7	48.39	0
09/01/2004 13:00:00	81.9	83.3	80.8	43.94	0
09/01/2004 14:00:00	82.3	83.8	80.8	43.96	0
09/01/2004 15:00:00	82.2	83.2	80.7	45.69	0
09/01/2004 16:00:00	83	83.6	82.4	44.78	0
09/01/2004 17:00:00	82.2	83.3	81.2	45.92	0

Date & Time	Average Temp (°F)	Maximum Temp (°F)	Minimum Temp (°F)	Relative Humidity (%)	Total Precip (in)
09/02/2004 07:00:00	65.5	67.5	63.4	83.7	0
09/02/2004 08:00:00	70	72.1	67.2	73.51	0
09/02/2004 09:00:00	73.3	74.8	71.8	65.58	0
09/02/2004 10:00:00	75.1	76.6	74	63.07	0
09/02/2004 11:00:00	76.6	78	75.5	59.23	0
09/02/2004 12:00:00	78.1	79.3	76.9	54.82	0
09/02/2004 13:00:00	79.4	81.1	78.3	52.66	0
09/02/2004 14:00:00	80.6	81.8	79.9	48.72	0
09/02/2004 15:00:00	80.9	81.6	80.3	48.27	0
09/02/2004 16:00:00	81	81.8	80.1	47.95	0
09/02/2004 17:00:00	80.3	81.5	79.1	49.74	0

APPENDIX C.   SOIL MOISTURE

Demonstrator: BLACKHAWK

Date: 8/24/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration Lanes	0 to 6	1.0	0.8
	6 to 12	20.2	20.0
	12 to 24	28.3	28.2
	24 to 36	35.4	35.2
	36 to 48	39.0	39.0
Blind Grid/Moguls	0 to 6	3.5	3.4
	6 to 12	25.0	25.0
	12 to 24	39.2	39.1
	24 to 36	36.1	36.0
	36 to 48	40.0	39.7

Demonstrator: BLACKHAWK

Date: 8/25/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	65.0	65.0
	6 to 12	73.7	73.6
	12 to 24	79.0	78.9
	24 to 36	55.0	55.0
	36 to 48	52.0	51.8
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	21.1	21.0
	6 to 12	5.8	5.7
	12 to 24	19.1	19.1
	24 to 36	26.3	26.1
	36 to 48	52.1	52.0
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 8/26/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	64.7	64.5
	6 to 12	73.7	73.5
	12 to 24	78.4	78.3
	24 to 36	54.7	54.7
	36 to 48	51.4	51.3
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	20.8	20.7
	6 to 12	5.6	5.5
	12 to 24	19.0	18.8
	24 to 36	26.0	26.0
	36 to 48	51.7	51.5
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 8/27/2004
Times: 0730 hours, 1700 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	64.5	64.4
	6 to 12	73.4	73.2
	12 to 24	78.1	78.2
	24 to 36	54.5	54.6
	36 to 48	51.5	51.4
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	20.5	20.2
	6 to 12	5.3	5.3
	12 to 24	18.7	18.6
	24 to 36	25.8	25.7
	36 to 48	51.4	51.4
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 8/28/2004
Times: 0800 hours, 1600 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	64.3	64.3
	6 to 12	73.2	73.0
	12 to 24	78.0	77.7
	24 to 36	54.4	54.1
	36 to 48	51.4	51.5
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	20.0	20.0
	6 to 12	5.1	5.0
	12 to 24	18.4	18.5
	24 to 36	25.4	25.2
	36 to 48	51.3	51.4
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 8/30/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	64.2	64.2
	6 to 12	72.7	72.8
	12 to 24	77.5	77.4
	24 to 36	54.0	54.0
	36 to 48	51.2	51.3
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	19.8	19.7
	6 to 12	5.3	5.2
	12 to 24	18.2	18.0
	24 to 36	25.3	25.3
	36 to 48	51.4	51.4
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 8/31/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	64.0	
	6 to 12	72.5	
	12 to 24	77.1	
	24 to 36	53.7	
	36 to 48	51.2	
Wooded Area	0 to 6	13.4	13.2
	6 to 12	5.8	5.8
	12 to 24	5.9	5.8
	24 to 36	55.5	55.4
	36 to 48	57.5	57.2
Open Area	0 to 6	19.5	
	6 to 12	5.1	
	12 to 24	18.0	
	24 to 36	25.1	
	36 to 48	51.6	
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Demonstrator: BLACKHAWK

Date: 9/1/2004
Times: 0800 hours, 1800 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	63.7	63.4
	6 to 12	72.4	72.4
	12 to 24	77.1	77.0
	24 to 36	53.2	53.2
	36 to 48	51.3	51.2
Wooded Area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	19.3	19.2
	6 to 12	5.0	4.8
	12 to 24	17.7	17.6
	24 to 36	25.0	24.9
	36 to 48	51.4	51.3
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6	3.0	2.8
	6 to 12	24.7	24.6
	12 to 24	38.7	38.7
	24 to 36	35.8	35.7
	36 to 48	39.2	39.0

Demonstrator: BLACKHAWK

Date: 9/2/2004
Times: 0800 hours, 1700 hours

Probe Location:	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	63.0	62.8
	6 to 12	72.0	72.1
	12 to 24	76.7	76.5
	24 to 36	52.8	52.6
	36 to 48	51.0	51.1
Wooded Area	0 to 6	14.0	14.0
	6 to 12	5.4	5.5
	12 to 24	5.9	5.6
	24 to 36	55.7	55.6
	36 to 48	57.6	57.5
Open Area	0 to 6	18.8	18.7
	6 to 12	4.5	4.6
	12 to 24	17.3	17.1
	24 to 36	24.6	24.5
	36 to 48	51.0	51.1
Calibration Lanes	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind Grid/Moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

APPENDIX D. DAILY ACTIVITY LOGS

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/23/2004	3	CALIBRATION LANE	845	1740	535	INITIAL MOBILIZATION	1	INITIAL MOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	750	1055	185	INITIAL MOBILIZATION	1	INITIAL MOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1055	1115	20	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1115	1230	75	INITIAL MOBILIZATION	1	INITIAL MOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1230	1315	45	CALIBRATE	2	CALIBRATE WITH METAL SPIKE CALIBRATE	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1315	1350	35	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1350	1405	15	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1405	1445	40	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	CALIBRATION LANE	1445	1505	20	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	BLIND TEST GRID	1505	1615	70	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	BLIND TEST GRID	1615	1640	25	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
8/24/2004	3	BLIND TEST GRID	1640	1715	35	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/25/2004	3	OPEN FIELD	740	905	85	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	905	925	20	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	925	1015	50	EQUIPMENT FAILURE	6	NOT RECEIVING GPS SATELLITES	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1015	1115	60	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1115	1125	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1125	1200	35	EQUIPMENT FAILURE	6	NOT RECEIVING GPS SATELLITES	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1200	1315	75	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1315	1330	15	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1330	1450	80	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1450	1500	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1500	1555	55	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1555	1605	10	DOWNTIME MAINTENANCE CHECK	7	DOWNLOAD DATA CHANGE DAT5A LOGGER	GPS	NA	LINEAR	RAINY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/25/2004	3	OPEN FIELD	1605	1630	25	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1630	1640	10	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	RAINY	MUDDY
8/25/2004	3	OPEN FIELD	1640	1655	15	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	RAINY	MUDDY
8/26/2004	3	OPEN FIELD	840	905	25	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	905	935	30	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	935	1110	95	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1110	1120	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1120	1315	115	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1315	1330	15	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY, DATA LOGGER	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1330	1450	80	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1450	1500	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1500	1625	85	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/26/2004	3	OPEN FIELD	1625	1640	15	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY
8/26/2004	3	OPEN FIELD	1640	1655	15	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
8/27/2004	3	OPEN FIELD	755	830	35	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	830	905	35	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	905	1025	80	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1025	1035	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1035	1205	90	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1205	1210	5	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1210	1340	90	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1340	1350	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY, DATA LOGGER	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1350	1500	70	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1500	1515	15	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/27/2004	3	OPEN FIELD	1515	1625	70	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1625	1640	15	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
8/27/2004	3	OPEN FIELD	1640	1705	25	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/03	3	OPEN FIELD	755	840	45	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	840	905	25	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	905	1015	70	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1015	1025	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1025	1250	155	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1250	1300	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY, DATA LOGGER	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1300	1425	85	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1425	1445	20	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
8/28/2004	3	OPEN FIELD	1445	1500	15	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/30/2004	3	OPEN FIELD	815	840	25	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	840	915	35	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	915	1020	65	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1020	1030	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1030	1145	75	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1145	1155	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY, DATA LOGGER	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1155	1310	75	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1310	1320	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1320	1415	55	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1415	1455	40	EQUIPMENT FAILURE	6	NOT RECEIVING GPS SATELLITES	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1455	1540	45	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/30/2004	3	OPEN FIELD	1540	1605	25	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/30/2004	3	OPEN FIELD	1605	1630	25	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	OPEN FIELD	755	825	30	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	OPEN FIELD	825	850	25	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	OPEN FIELD	850	930	40	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	930	1030	60	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1030	1040	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1040	1130	50	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1130	1230	60	DAILY START STOP	3	EQUIPMENT PREP	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1230	1240	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1240	1330	50	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1330	1355	25	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1355	1550	115	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
8/31/2004	3	WOODS	1550	1600	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1600	1715	75	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1715	1735	20	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	CLOUDY	MUDDY
8/31/2004	3	WOODS	1735	1800	25	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	CLOUDY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	755	820	25	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	820	930	70	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	930	1035	65	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1035	1045	10	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1045	1205	80	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1205	1215	55	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1215	1300	45	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1300	1325	25	EQUIPMENT BREAKDOWN	6	MAGS NOT COLLECTING DATA	GPS	NA	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1325	1400	35	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1400	1410	10	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1410	1455	45	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1455	1510	15	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1510	1540	30	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1540	1550	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1550	1630	40	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1630	1650	20	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
9/1/2004	3	MOGULS OPEN FIELD 90%/10%	1650	1710	20	DAILY START STOP	3	BREAKDOWN END OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	750	820	30	DAILY START STOP	3	START OF OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	820	850	30	CALIBRATE	2	CALIBRATE WITH METAL SPIKE	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	850	940	50	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	OP Stat Code	Operational Status - Comments	Track Method	Track Method = Other Explain	Pattern	Field Conditions	
9/2/2004	3	OPEN FIELD	940	1030	50	LUNCH/BREAK	5	LUNCH/BREAK	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	1030	1130	60	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	1130	1140	10	DOWNTIME MAINTENANCE CHECK	7	CHANGE BATTERY	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	WOODS	1140	1200	20	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	1200	1255	55	COLLECT DATA	4	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	1255	1525	150	DOWNTIME MAINTENANCE CHECK	7	DATA CHECK	GPS	NA	LINEAR	SUNNY	MUDDY
9/2/2004	3	OPEN FIELD	1525	1700	95	DEMOBILIZATION	10	DEMOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

APPENDIX F. ABBREVIATIONS

AEC	=	U.S. Army Environmental Center
APG	=	Aberdeen Proving Ground
ASCII	=	American Standard Code for Information Interchange.
ATC	=	U.S. Army Aberdeen Test Center
EM	=	electromagnetic
EMI	=	electromagnetic interference
EMIS	=	Electromagnetic Induction Spectroscopy
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
EQT	=	Army Environmental Quality Technology Program
FPGA	=	Field Programmable Gate Array
GPS	=	Global Positioning System
JPG	=	Jefferson Proving Ground
PM	=	project manager
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real time kinematic
RTS	=	Robotic Total Station
SERDP	=	Strategic Environmental Research and Development Program
UTM	=	Universal Transverse Mercator
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground